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Analysis of the Family Life Surveys in Indonesia: The Contribution of Wheat Flour Fortification to Improving Anemia

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B.S.
Texas A&M University
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An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Global Epidemiology
2014

Abstract

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By Katherine Lynn Kendrick

Objective

Mandatory wheat flour fortification with electrolytic iron, zinc, thiamine, riboflavin, and folic acid became effective in Indonesia in 2002. There have been no evaluations of the effectiveness of wheat flour fortification on improving hemoglobin concentrations. This study estimated the contribution of wheat flour fortification to the change in hemoglobin concentration and anemia prevalence from the period before to after the introduction of mandatory fortification.

Methods

The Indonesia Family Life Survey is a longitudinal study that followed over 30,000 Indonesians from 1993 to 2008. Data from 5,828 non-pregnant women of child-bearing age with hemoglobin measurements in 1997, 2000, and 2007 were analyzed. Anemia prevalence was calculated, adjusting for smoking status and altitude. Logistic regression was used to predict the effect of confounders on anemia status, while linear regression was used for hemoglobin concentration.

Results

Anemia prevalence significantly decreased ($p<0.0001$) from the pre-fortification period during 1997-2000 (34.0%) to the post-fortification period in 2007 (25.2%). The main variable of interest, whether a household purchased foods containing heme iron and flour, only heme iron, only flour, or neither in the past week was not significantly associated with either hemoglobin concentration or anemia status.

Conclusion

Wheat flour fortification does not appear to have significantly contributed to the reduction in anemia prevalence among women of child-bearing age in Indonesia. It is recommended that the fortification iron source be changed from electrolytic iron to a more bioavailable form.

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Acknowledgements

I'd like to thank my advisor, Helena Pachón, for all of her guidance and help making this project possible, and my advisor, Harland Austin, for his epidemiologic advice. I'd also like to thank Karen Codling and Annoek van den Wijngaart from the Flour Fortification Initiative (FFI), Siti Muslimatun, Helda Khusun, Otte Santika, and Linda Oey from the Southeast Asian Ministers of Education Organization—Regional Center for Food and Nutrition (SEAMEO-RECFON), Bondan Sikoki from SurveyMETER, Harriet Torlesse and Ninik Sukotjo from UNICEF, and Pak Soekirman and Pak Sunawang from the Indonesian Nutrition Foundation for Food Fortification. Finally, I'd like to thank FFI, the Micronutrient Initiative, the Rollins School of Public Health Global Field Experience Fund, and SEAMEO-RECFON for funding this project.

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Introduction

Iron deficiency is the most common micronutrient deficiency in the world, and is an important cause of anemia in developing countries; worldwide, it is estimated that about 50% of anemia cases are due to iron deficiency (1-3). A systematic analysis of anemia trends between 1995 and 2011 found the global prevalence of anemia among non-pregnant women to have decreased from 33% (95% CI 29, 37) in 1995 to 29% (95% CI 24, 35) in 2011 and the prevalence in East and Southeast Asia to have decreased from 29% (95% CI 22, 39) in 1995 to 21% (95% CI 12, 36) in 2011 (2). In Indonesia, the prevalence of anemia among non-pregnant women of reproductive age is estimated to be 33.1% (95% CI 13.1, 61.8), high enough to be classified as a moderate public health problem by the World Health Organization (WHO) (3). In adults, anemia can cause weakness and fatigue, resulting in decreased productivity in the manual labor sector and decreased work capacity (4, 5). In addition, there is evidence that anemia-related cognitive defects are directly linked with lower future earnings (6, 7).

One strategy for improving iron deficiency anemia is food fortification (8). Worldwide, flour fortification with iron, folic acid, and other nutrients has seen mixed results in decreasing the prevalence of anemia. For example, a study in central Asia found that anemia prevalence among women of reproductive age decreased after flour fortification with electrolytic iron was introduced in Azerbaijan, Kazakhstan, and Uzbekistan, but not in Mongolia and Tajikistan (9). In Sri Lanka, flour fortified with electrolytic iron showed no effect on hemoglobin concentrations in non-pregnant women (10). A study in Brazil found that fortifying wheat and corn flour with iron had no impact on reducing the prevalence of anemia in children, while a study in Venezuela found that wheat and corn flour fortification with iron initially decreased the prevalence of anemia, but that several years later the prevalence had returned to pre-fortification levels (11, 12).

Wheat flour consumption is relatively low, but slowly rising in Indonesia. It is the second largest source of carbohydrates from staple foods, primarily in the form of instant noodles, fried snacks, meat noodle dishes, and sweet breads (13). In 2008, more than 90% of Indonesian households consumed some flour, increasing from just over 80% in 1996; average daily consumption of flour also increased from 46.6 g per capita in 1996 to 51.5 g per capita in 2008 (13). This trend, along with other factors such as economic feasibility, production and distribution considerations, appearance, and taste, made wheat flour a logical choice for fortification (14).

Legislation for mandatory wheat flour fortification in Indonesia was passed in 2001 and has been in effect since February of 2002, when the Ministry of Industry and Trade issued a decree that called for mandatory application of the national standard of Indonesia (SNI) for fortified wheat flour (15, 16). According to the SNI, both imported and domestically produced wheat flour for use in food must be fortified with 50 ppm iron, 30 ppm zinc, 2.5 ppm thiamine, 4 ppm riboflavin, and 2 ppm folic acid (16). However, these nutrient levels do not meet current international flour fortification recommendations; for a country such as Indonesia with less than 75 g of wheat flour consumption per person per day, the following levels are recommended: 60 ppm iron in the form of ferrous sulfate or ferrous fumarate, 95 ppm zinc, and 5 ppm folic acid (no recommendations are given for thiamine or riboflavin) (17). Inadequate iron fortification is particularly an issue since Indonesian mills likely use electrolytic iron because of its low cost; however, this iron compound is poorly absorbed by the body and has a low bioavailability. In order to have a comparable effect as ferrous sulfate or ferrous fumarate, double the amount of electrolytic iron is needed; since high levels of electrolytic iron negatively affect sensory properties of wheat flour, it is not recommended for use in countries with less than 75 g of wheat flour consumption per person per day such as Indonesia (8, 17, 18).

To date, there has only been one study to evaluate the effectiveness of mandatory wheat flour fortification in Indonesia (19). Using a cross-sectional design to obtain information on wheat flour consumption among poor families in North Jakarta, Sandjaja et al. found no clear association between prevalence of anemia and intake of fortified wheat flour. However, the study has several limitations including its use of a one-day dietary recall and its limited study population.

There are two main objectives for this study: to quantify the change in hemoglobin concentration and anemia prevalence between the period before and after the introduction of mandatory wheat flour fortification in Indonesia for non-pregnant women of childbearing age, and to estimate the association between both hemoglobin and anemia and the proportion of a household's food expenditures spent on foods containing flour, which is used as a proxy for consumption. This study is unique in that it is the first to evaluate the impact of Indonesia's mandatory wheat flour fortification program on a large sample of the population. In addition, by using longitudinal data, this study is able to evaluate impact over time.

Methods

This study was exempt from Institutional Review Board review since the data used in the analysis did not contain any identifying information on subjects.

Data Source

The Indonesia Family Life Survey (IFLS) is an ongoing longitudinal survey conducted by the RAND Corporation that follows about 7,200 families in Indonesia (20). The survey is addressed to a population that is representative of about 83% of the Indonesian population and consists of over 30,000 individuals who lived in 13 of the 27 Indonesian provinces at the start of the survey in 1993 (20). The first wave of surveys, IFLS1, was conducted in 1993/1994, and four years later the second wave, IFLS2, was conducted in 1997, covering 94% of the original IFLS1 families (21). The third wave, IFLS3, was conducted in 2000 and reached 95% of the original IFLS1 families (22). Finally, the most current wave, IFLS4, was conducted in 2007/2008 and covered 94% of the original IFLS1 families (23).

The IFLS is unique in that it is the only large-scale, longitudinal, multipurpose survey conducted in Indonesia (21-23). By collecting data at the individual and household levels across multiple years, the IFLS allows for the analysis of changes in behavior and health status over time. Since hemoglobin measurements were not collected during IFLS1, only the most recent three waves of the survey were used in this analysis. Since mandatory wheat flour fortification was introduced in Indonesia in 2002, IFLS2 and IFLS3, conducted in 1997 and

2000 respectively, were used to represent the pre-fortification period while IFLS4, conducted in 2007/2008 was used to represent the post-fortification period.

Study Population

This analysis was limited to women who were aged 15-49 y during IFLS2, who had hemoglobin data from IFLS4 and either IFLS2 or IFLS3 (or both), who were not currently taking medication for anemia during any survey wave, and who were not pregnant at the time of hemoglobin measurement for any of the three survey waves. The final study population consisted of the same 5,828 women in each survey wave.

Data Overview and Variable Creation

Due to the nature of the IFLS design, a single respondent could have answered several separate survey books within the same survey wave that covered similar questions, such as marital status, pregnancy status, and age (21-23). Every effort was made to correct inconsistent answers, deferring to the "ptrack" file when possible, which contained RAND's "best guess" for certain variables; these variables were constructed by RAND in the same way for each survey wave using all the data available (23).

During each survey way, hemoglobin measurements were taken in the field using the HemoCue Hb301 analyzer, which was recalibrated daily; a lancet was used to prick the finger, and a drop of blood was collected into a cuvette that was inserted into the HemoCue (21-24). Since the IFLS contains information on hemoglobin concentrations but not anemia status, anemia status was calculated as follows: a woman with hemoglobin <12.0 g/dL was considered anemic while a woman with hemoglobin ≥12.0 g/dL was considered non-anemic (25). All hemoglobin concentrations were adjusted for smoking status and altitude in accordance with WHO recommendations (25). Smoking status was determined by number of cigarettes smoked per day, and altitude was determined by household location at the *kecamatan* (subdistrict) level using Google Earth (21-23, 26).

Since individual or household consumption data were not available, the total of household food expenditures and monetary values of food items produced or received in the past week were used as a proxy. The IFLS asked households about specific groups of food, which were categorized into flour- and heme-containing foods for the purpose of this analysis (Table 1). Heme-containing foods were included as a separate category since heme iron is well absorbed by the body (average absorption is about 25%) and has a large impact on body iron levels (27). Individual households were also categorized into four groups based on their food expenditures: those that purchased at least one type of flour-containing foods and at least one type of heme-containing foods, those that purchased flour-containing foods but not heme-containing foods, those that purchased heme-containing foods but not flour-containing foods, and those that purchased neither flour- nor heme-containing foods. Total absolute household expenditures on heme-containing foods were calculated by adding household expenditures on heme-containing foods to the monetary value of heme-containing foods produced or received in the past week. Similarly, total absolute household expenditures on flour-containing foods were calculated by adding household expenditures on flour-containing foods to the monetary value of flour-containing foods produced or received in the past week. Percent of weekly household food expenditures spent on heme foods was calculated by dividing total absolute expenditures on heme-containing foods by the sum of expenditures on all foods and monetary values of all foods produced or received in the past week. Similarly, percent of weekly household food expenditures spent on flour-containing foods was calculated by dividing total absolute expenditures on flour-containing foods by the sum of expenditures on all foods and monetary values of all foods produced or received in the past week.

Highest level of education attended was reclassified according to the levels described in Indonesian Law No. 2/1989: no education, pre-school, basic education, secondary education, higher education, and other (28). Pre-school included kindergarten; basic education included elementary school, Islamic elementary school, general junior high school, vocational junior high school, and Islamic junior high school; secondary education included general senior high school, vocational senior high school, and Islamic senior high school; higher education included junior college, college D1, D2, and D3, university bachelor, master, and doctorate, and university S1, S2, and S3; and other included adult education A, B, and C, open university, general Islamic school, and school for the disabled (21-23).

Household sanitation was determined by assessing the following conditions: the presence of human and animal waste, piles of trash, and stagnant water surrounding the home. If any of these were observed, a household was classified as having poor sanitation.

Implausible values were handled as follows: reported heights less than 91.4 cm were changed to missing and reported weights less than 22.7 kg were changed to missing.

Statistical Analyses

All analyses were performed using SAS 9.3 Statistical Software (SAS Inc., Cary, NC) and a significance level of α=0.05. Descriptive analyses were performed to test whether household and individual characteristics of interest changed between survey waves using either the Wilcoxon signed-rank test for non-normally distributed data or a chi-square/Fisher's exact test. To achieve the first objective, to quantify the change in hemoglobin concentration and anemia prevalence between the periods before and after the introduction of mandatory wheat flour fortification in Indonesia, hemoglobin data from IFLS2 and IFLS3 was combined to represent the pre-fortification period while data from IFLS4 represented the post-fortification period. Average adjusted hemoglobin concentration was calculated for the pre-fortification period and compared to the post-fortification period using a paired t-test. Pre-fortification anemia prevalence was compared to the post-fortification anemia prevalence using a chi-squared test.

Multiple analyses were performed on variables stratified by household food spending category: households that purchased both heme- and flour-containing foods, flour- but not heme-containing foods, heme- but not flour-containing foods, or neither heme- nor flour-containing foods. To determine if the percentage of a household's income spent on flour-containing foods and on heme-containing foods was different for each spending category and each survey wave, Tukey's multiple comparison test was applied. Similarly, Tukey's multiple comparison test was applied to determine if adjusted hemoglobin concentration was different for each spending category and each survey wave. Logistic regression was used to determine if anemia status was different across spending categories and across survey waves.

To assess the association between fortification and hemoglobin concentration and between fortification and anemia status, the following explanatory variables were considered: marital status, age, height, weight, smoking status, number of cigarettes smoked per day, whether a woman took iron pills in the last month, the number of iron pills taken in the last month, highest education level attended, total number of pregnancies, household size, household overall monthly expenditures, household weekly food expenditures, percent of household food expenditures spent on heme-containing foods, percent of household food expenditures spent on flour-containing foods, household spending category, whether a household lives in an urban area, poor sanitation, and province of residence.

A linear regression model for adjusted hemoglobin concentration was developed using SAS's proc mixed procedure to account for the repeated measures on each individual woman and the possibility for multiple women living in the same household. Explanatory variable selection was performed by testing the significance of bivariate associations between adjusted hemoglobin concentration and the explanatory variables previously mentioned. Significant variables were included in a multivariate linear regression model, and backwards selection was used to determine the final model.

A logistic regression model for anemia status was developed using SAS's proc glimmix procedure to account for the repeated measures on each individual woman and the possibility for multiple women living in the same household. Variable selection was performed by including each explanatory variable in a model containing the main exposure of interest, survey wave, and assessing whether the odds ratio (OR) for anemia status changed from that in the baseline model containing only survey wave by more than 10%. Those variables that had a large impact on the OR were included in a final model containing all of these variables.

Results

In total, 5,828 non-pregnant women of reproductive age were included in the analysis (Table 2). These women represented 4,665 households in IFLS2, 4,998 in IFLS3, and 5,382 in IFLS4 as women moved away and started their own households. All continuous variables were found to be non-normally distributed using the Kolmogorov-Smirnov test ($p<0.01$). Median household size was 5 people in IFLS2 and IFLS3 and lower at 4 people in IFLS4. Median monthly household expenditures were 381,329.2 rp in IFLS2, 735,079.2 in IFLS3, and 1,655,991.8 in IFLS4 (expenditures were reported as nominal values). Median household weekly expenditures on all foods were 4,4025.0 rp in IFLS2, 90,300.0 in IFLS3, and 184,500.0 in IFLS4. Median household weekly expenditures on flour foods were 2,700.0 rp in IFLS2, 6,675.0 in IFLS3, and 15,000.0 in IFLS4. The median percentage of a household's weekly food expenditures spent on flour foods was 6.2% in IFLS2, and increased to 7.5% in IFLS3 and 8.0% in IFLS4. Median household weekly expenditures on heme foods were 5,000.0 rp in IFLS2, 10,000.0 in IFLS3, and 19,000.0 in IFLS4. The median percentage of a household's weekly food expenditures spent on heme foods was 11.1% in IFLS2, 11.8% in IFLS3, and decreased to 10.3% in IFLS4. For all three survey waves, most households purchased both heme and flour foods in the past week. The second highest number of households purchased flour but not heme foods, followed by heme but not flour foods; the lowest number of households purchased neither heme nor flour foods. Across survey waves, an increasing number of households purchased both heme and flour foods or flour but not heme foods. Conversely, a decreasing number of households purchased heme but not flour foods or neither heme nor flour foods. In IFLS2 and IFLS3, less than half of the women lived in urban areas (47.7% and 48.6%, respectively). However, in IFLS4, more than half of the women lived in urban areas (53.8%). The percent of households with poor sanitation remained relatively constant across survey waves; in IFLS2, IFLS3, and IFLS4, 19.4%, 20.7%, and 20.4% of households had poor sanitation, respectively. The highest percentage of households lived in East, West, and Central Java provinces in all three survey waves; as households branched out and moved, additional provinces were represented.

The women's median age was 32 years in IFLS2, and as expected, increased to 35 in IFLS3 and 42 in IFLS4. The median height of the women was 150 cm in all three waves; the median weight was 48.6 kg in IFLS2, 50.1 kg in IFLS3, and 53.4 kg in IFLS4. The majority of the women were married in each of the survey waves; in IFLS2 70.2% were currently married, in IFLS3 74.2%, and in IFLS4 80.5%. A very small percentage of the women were current smokers; 2.0%, 2.4%, and 2.3% reported smoking in IFLS2, IFLS3, and IFLS4, respectively. Among current smokers, the mean number of cigarettes smoked per day was 6 in IFLS2 and 5 in IFLS3 and IFLS4. In IFLS2, 7.8% of women reported taking iron pills within the last month, which decreased to 3.5% in IFLS3 and 5.0% in IFLS4. Among those women who took iron pills within the last month, they took a median of 10 pills in IFLS2 and IFLS3 and 8 pills in IFLS4. Across all three survey waves the highest percentage of women reported basic education as their highest level attended, followed by secondary education and no education. The percent of women who had attended higher education increased from 4.8% in

IFLS2 to 8.9% in IFLS4. The median total number of pregnancies per woman remained relatively low at 1 pregnancy for IFLS2 and IFLS3 and 2 for IFLS4.

Median adjusted hemoglobin concentration was 12.5 g/dL in IFLS2, decreased to 12.4 g/dL in IFLS3, and increased to 12.8 g/dL in IFLS4. Likewise, anemia prevalence increased from 33.9% in IFLS2 to 36.1% in IFLS3, then decreased to 25.2% in IFLS4.

Since IFLS2 and IFLS3 both represent the pre-fortification period in Indonesia, hemoglobin concentrations were averaged for these two surveys and compared to those in IFLS4, which represented the post-fortification period (Table 3). The average change from pre- to post- fortification was 0.32 g/dL, a significant difference ($p<0.0001$). Similarly, anemia prevalence decreased from 34.0% pre-fortification to 25.2% post-fortification, which was also a significant difference ($p<0.0001$).

Tukey's multiple comparison test was used to determine if the average percentage of a household's weekly food expenditures spent on heme and flour foods was different for each survey wave and each household spending category (Table 4). Average percent spent on heme foods was found to be significantly different ($p<0.05$) between IFLS2 and IFLS3, between IFLS2 and IFLS4, and between IFLS3 and IFLS4 among households that purchased both heme and flour foods; among households that purchased heme but not flour foods, no significant difference was found between IFLS2 and IFS3, between IFLS2 and IFLS4, or between IFLS3 and IFLS4. Average percent spent on flour foods was found to be significantly different between IFLS2 and IFLS3, between IFLS2 and IFLS4, and between IFLS3 and IFLS4 among households that purchased both heme and flour foods; among households who purchased flour but not heme foods, there was a significant difference between IFLS2 and ILFS3 and between IFLS2 and IFLS4, but not between IFLS3 and IFLS4. Within IFLS2, the percentage spent on heme foods significantly differed between spending categories, but the percentage spent on flour foods did not. The same trend was seen within IFLS3. Within IFLS4, the percentage spent on heme foods did not significantly differ between spending categories, but the percentage spent on flour foods did.

Using Tukey's multiple comparison test, average household weekly expenditures on all foods was found to be significantly different ($p<0.05$) between IFLS2 and IFLS3, between IFLS2 and IFLS4, and between ILFS3 and IFLS4 among women whose households purchased both heme and flour foods (Table 5). This same trend was seen among women whose households purchased flour but not heme foods. Among women whose households purchased heme but not flour foods, average household weekly expenditures on all foods was significantly different between IFLS2 and ILFS4 and between IFLS3 and IFLS4, but not between IFLS2 and IFLS3. Among women whose households purchased neither heme nor flour foods, average household weekly expenditures on all foods was significantly different between IFLS2 and IFLS3, between IFLS2 and IFLS4, and between ILFS3 and IFLS4. Within IFLS2, average household weekly expenditures on all foods was significantly different between all pairs of spending categories except between the flour, no heme and the heme, no flour spending categories and between the flour, no heme and the no flour no heme spending categories. Within IFLS3 average household weekly expenditures on all foods was significantly different between all pairs of spending categories except between the flour, no heme and the heme, no flour spending categories, between the flour, no heme and the no heme, no flour spending categories, and between the heme, no flour and the no heme, no flour spending categories. Within IFLS4, average household weekly expenditures on all foods was not significantly different between any pair of spending categories except between the heme and flour and the flour, no heme spending categories and between the heme and flour and the no heme, no flour spending categories.

Using Tukey's multiple comparison test, average adjusted hemoglobin concentrations were found to be significantly different ($p<0.05$) between IFLS2 and IFLS3, between IFLS2 and IFSL4, and between IFLS3 and IFLS4 among women whose households purchased both heme and flour foods (Table 6). Among women whose households purchased flour but not heme foods, average hemoglobin concentrations were not significantly different between IFLS2 and IFLS3 or between IFSL2 and IFSL4 but were significantly different between IFLS3 and IFLS4. Similarly, among women whose households purchased heme but not flour foods, average hemoglobin concentrations were not significantly different between IFLS2 and IFLS3 or between IFLS2 and IFLS4 but were significantly different between IFLS3 and IFLS4. Among women whose households purchased neither heme nor flour foods, average hemoglobin concentrations were not significantly different between IFLS2 and IFLS3, between IFSL2 and IFLS4, nor between IFLS3 and IFSL4. Within IFLS2, average hemoglobin concentrations were not significantly different between any pairs of spending category; this was also seen within IFLS3. Within IFLS4, the only two spending categories with significantly different average hemoglobin concentrations were women whose households purchased both heme and flour foods and women whose households purchased flour but not heme foods.

Logistic regression was used to determine if anemia status differed across survey waves by spending category and across spending category by survey wave (Table 7). Among women whose households purchased both heme and flour foods, there was a significant difference in anemia status between IFLS2 and IFLS4 and between IFLS3 and IFLS4. The same trend was seen among women whose households purchased flour but not heme foods. Among women whose households purchased heme but not flour foods, there was a significant difference in anemia status between IFLS3 and IFLS4 but not between IFLS2 and IFLS4. Among women whose households purchased neither heme nor flour foods, anemia status was not significantly different between IFLS2 and IFLS4 or between IFLS3 and IFLS4. Within IFLS2, anemia status was not significantly different among women whose households purchased any combination of heme or flour foods and women whose households purchased neither heme nor flour foods. The same trend was seen within IFLS3 and IFLS4.

Average adjusted hemoglobin concentration and anemia prevalence were also stratified by whether women lived in an urban or rural area. Adjusted hemoglobin concentration was found to be significantly different among women who lived in urban and rural areas in IFLS2; average adjusted hemoglobin concentration was 12.3 g/dL among women who lived in urban and 12.4 g/dL in rural areas (Table 8). No difference in average adjusted hemoglobin concentration was seen among women who lived in urban and rural areas in

IFLS3 or IFLS4. No difference in anemia prevalence was seen among women who lived in urban and rural areas in any survey wave (Table 9).

Considering the bivariate associations between adjusted hemoglobin concentration and independent variables of interest, the following variables were found to have a significant linear association with adjusted hemoglobin concentration: weight, taking iron pills in the last month, number of iron pills taken in the last month, household size, monthly household expenditures, household weekly expenditures on all foods, percent of household weekly food expenditures spent on flour foods, highest level of education attended, province of residence, and survey wave (Table 10). These variables were included in a multivariate linear model, and backwards elimination was used to eliminate variables until all variables in the model were statistically significant. Interaction terms between household size and monthly household expenditures and between survey wave and percent of household weekly food expenditures spent on flour foods were found to be non-significant (p=0.8331 and p=0.2119, respectively). No other interaction terms were able to be considered and have the model still run. Similarly, random effects were not able to be considered and have the model still run. The final linear model for adjusted hemoglobin concentration included the following variables: weight, number of iron pills taken in the last month, household size, percent of household weekly food expenditures spent on flour foods, province of residence, and survey wave (Table 11). The nominal values of household weekly food expenditures on heme foods and flour foods were also found to have a significant bivariate linear association with adjusted hemoglobin concentration. When these variables were used to build a model in place of the percent of household weekly food expenditures on heme foods and the percent of household weekly food expenditures on flour foods, the final linear model for adjusted hemoglobin concentration included the following variables: weight, number of iron pills taken in the last month, household size, household weekly food expenditures on flour foods, household weekly expenditures on all foods, province of residence, and survey wave. When household weekly expenditures on all foods was divided into quintiles, it was found to have a significant bivariate linear association with adjusted hemoglobin concentration. When quintiles were used in place of the nominal value of household weekly expenditures on all foods, the final linear model was the same as it was when nominal values were used.

A logistic model for anemia status was developed using survey wave as the main exposure. Assessment of potential confounders resulted in only one variable, age, that changed the OR for the effect of survey wave on anemia status by more than 10% (Table 12). Interaction terms between age and IFLS2 and between age and IFLS3 were non-significant and not included in the model ($p=0.2147$ and $p=0.2475$, respectively). Random effects were not able to be considered and have the model still run. Therefore, the final logistic model for anemia status included only survey wave and age (Table 13). The odds of anemia in IFLS2 were 1.74 (95%CI 1.67, 1.82) times those in IFSL4, and the odds of anemia in IFLS3 were 1.83 (95%CI 1.76, 1.90) times those in IFLS4.

Discussion

On average, hemoglobin concentration increased and anemia prevalence decreased from the pre- to post-mandatory wheat flour fortification period in Indonesia. Within the pre-fortification period, median hemoglobin concentration slightly decreased from IFLS2 to IFLS3, but then increased from IFLS3 to IFLS4. Similarly, anemia prevalence increased from IFLS2 to IFLS3, but decreased from IFLS3 to IFLS4. One possible explanation for this decrease in hemoglobin concentration and increase in anemia prevalence between IFLS2 and IFLS3 is the 1997 Asian financial crisis. Beginning in mid-1997, Indonesia experienced high inflation and increased unemployment, leading to a reduction in consumer spending power (29). As food prices increased, intake of nutrient-rich foods such as meats, eggs, and milk, decreased. Data from the Helen Keller International and Government of Indonesia Nutrition Surveillance System have shown that micronutrient deficiencies, particularly anemia, increased after the financial crisis, and that the increase is mainly explained by a decrease in consumption of micronutrient-rich foods (29). Therefore, it is not surprising that hemoglobin concentrations decreased and anemia prevalence increased during the aftermath of the financial crisis. Consequently, the increase in hemoglobin concentrations and decrease in anemia prevalence between IFLS3 and IFLS4 could be a result of recovery from the financial crisis; Indonesia's GDP increased from 165.021 billion USD in 2000 to 432.2167 billion USD in 2007 (30).

It was expected that two types of foods would impact hemoglobin concentration: animal foods rich in heme iron and foods containing fortified wheat flour. Therefore, households were categorized into four groups depending on whether they purchased only heme or only flour foods, both heme and flour foods, or neither. If fortification were effective, hemoglobin concentration would be expected to be higher among those who purchased both heme and flour foods compared to those who purchased only heme foods or neither heme nor flour foods. Similarly, anemia prevalence would be expected to be lower among those who purchased both heme and flour foods compared to those who purchased only heme foods or neither heme nor flour foods. During the post fortification period, no significant difference was seen in hemoglobin concentrations between spending categories that would indicate fortification had an impact. The only two spending categories that were significantly different in IFLS4 were women from households that purchased both heme and flour foods and women from households that purchased only flour foods, suggesting only heme foods had a positive impact on hemoglobin concentration. However, during the pre-fortification period, no significant differences were seen in hemoglobin concentrations across spending categories, which is not what would be expected if heme foods were impacting hemoglobin concentration. Looking within each spending category across survey waves, hemoglobin concentration was significantly different between IFLS3 and IFLS4 among women from households who purchased flour but not heme foods, indicating fortification may have had a positive impact. Since there was not a significant difference in the percent of food expenditures spent on flour foods between IFLS3 and IFLS4 for this group, it did not appear that this increase in average hemoglobin concentration was because of a change in purchasing habits. Hemoglobin concentration was also significantly different between IFLS3 and IFLS4 among women from households who purchased heme but not flour foods. Since there was no significant difference between the percent of food expenditures spent on heme foods between IFLS3 and IFLS4 among women whose households purchased only heme foods, it did not appear that the increase in hemoglobin concentration among this group could be explained by a difference in purchasing habits.

Considering anemia, there was not a significant difference between anemia prevalence among women from households who purchased neither heme nor flour foods and women from households in any other spending category for both the pre- and post-fortification period, indicating neither heme nor flour foods had an impact on anemia prevalence. Among women from households that purchased only flour foods, there was a significant difference in anemia prevalence between the pre- and post-fortification periods, indicating fortification may have had a positive impact. Anemia prevalence was also significantly different between IFLS3 and IFLS4 among women from households that purchased only heme but not flour foods. As described earlier, since there was not a significant difference between the percent of food expenditures spent on flour or heme foods between IFSL3 and IFLS4 for women from households that purchased only flour or only heme foods, respectively, it did not appear that the decrease in anemia prevalence could be explained by a difference in purchasing habits.

Using linear regression to model hemoglobin concentration also produced mixed results of the impact of fortification. Neither spending category nor percent of food expenditures spent on heme foods appeared to be linearly associated with hemoglobin concentration. However, there did appear to be a linear relationship between percent of food expenditures spent on flour foods and hemoglobin concentration when controlling for survey wave, weight, number of iron pills taken in the last month, household size, and province; for every one percent unit increase in the percent of food expenditures spent on flour foods, hemoglobin concentration increased by 0.006971 units, indicating that fortification may have had a positive impact on hemoglobin concentration. Number of iron pills taken in the last month also appeared to be linearly associated with hemoglobin concentration when controlling for survey wave, weight, percent of food expenditures spent on flour foods, household size, and province, although not in the expected direction; for every one pill increase in the number of iron pills taken, hemoglobin concentration decreased by 0.01073 g/dL. This may imply that iron pill supplementation was not having its intended effect, but it also could be a result of the very small percentage of women who reported taking any iron pills in the last month and recollection bias.

Using logistic regression to model anemia status, it appears that fortification has had no impact on anemia. Household spending category, percent of food expenditures spent on flour foods, and percent of food expenditures spent on heme foods did not confound the relationship between anemia status and survey wave, indicating that fortification cannot explain the change in anemia status over time. The only factor that appeared to confound the association between anemia status and survey wave was age; for every one year increase in age, the log odds of anemia increased by 0.01295 units. Although likely not because of fortification, anemia status did still decrease between the pre- and post-fortification periods; the odds of anemia in IFLS2 were 1.74 times those in IFLS4, and the odds of anemia in IFLS3 were 1.83 times those in IFLS4.

Although hemoglobin concentration increased and anemia prevalence decreased from the pre- to post-fortification period, it does not appear that mandatory wheat flour fortification can explain this change in hemoglobin concentration and anemia prevalence. The current standards in Indonesia for fortifying wheat flour with iron, zinc, and folic acid fall short of the WHO recommendations for countries like Indonesia with less than 75 g of wheat flour consumption per person per day. Not only does Indonesia use a lower amount of iron than recommended, but it also uses electrolytic iron, a form of iron with particularly low bioavailability, instead of the recommended iron forms ferrous sulfate or ferrous fumarate. Since deficiencies in zinc and folic acid are also known to cause anemia, issues with the amount and type of iron supplementation and the amount of folic acid and zinc supplementation may be preventing fortification from having its intended effect (27).

This study had several limitations, most notably the use of household food expenditure data to represent individual consumption data. Purchasing food does not necessarily imply consumption of that food. Additionally, household level data may not be an accurate representation of individual level data because of differences in intra-hosuehold food distribution (31). The IFLS questionnaire asked respondents about a wide variety of foods, but only in terms of broad groupings. When categorizing these food groups into flour- and heme-containing foods, a grouping was included if any of the foods contained flour or heme. Therefore, some groupings may contain food items with low or no amounts of flour or heme. Similarly, when categorizing households into spending categories, households were placed based on their expenditures on any or no flour and heme foods, rather than the amount spent on these foods. Therefore, no distinction was made between households that spent large amounts of money on heme or flour foods and those that only spent a small amount of money on these foods. In Indonesia, weekly household food expenditures may not be an accurate representation of typical habits; many households may only purchase certain foods on a monthly basis, which would not be reflected in weekly expenditure data.

Another important limitation is the assumption that anemia is a result of iron deficiency and not other causes such as malaria, hookworm infection, or thalassemia. Unfortunately, there is a lack of data in the IFLS on these other causes. Worldwide, it is estimated that 50% of anemia is caused by iron deficiency (3). In Indonesia, there are no clear estimates of the prevalence of iron deficiency anemia in non-pregnant women at a national level. A study in Jakarta found that among anemic women, 40% were iron deficient (32). A study of young adolescent girls in the rural coastal area of Indonesia found that 21.8% of anemia cases were iron deficiency anemia, and a study in Bali found that the prevalence of iron deficiency anemia in pregnant women was 46.2% (33, 34).

Malaria is endemic in Indonesia, but there is a lack of consistent data on the number of reported cases. According to the WHO's World Malaria Report 2008 and 2009, Indonesia had 161,285 reported malaria cases in 1997, 101,185 cases in 2000, and 1,140,424 cases in 2007 (35, 36). However, according to the WHO's World Malaria Report 2011, the number of cases in 2007 was less than

1,000,000 (exact numbers not available), and there was less than a 50% decrease in the number of confirmed malaria cases between 2000 and 2010 (37). The WHO's World Malaria Report 2013 showed a similar trend, reporting between 1.5 and 2.0 cases per 1,000 people in 2000 and in 2007/2008 (38). Therefore, it appears as though the number of malaria cases was fairly consistent across all three survey waves, indicating that malaria should not have a major impact on this study and cannot explain the observed trends in hemoglobin concentration and anemia status.

There are no estimates available for country level hookworm infection prevalence in Indonesia. However, a cross-sectional study in Bali of the adult population found that 3.3% of samples had hookworm anemia, or 12.2% of iron deficiency anemia cases (39).

Thalassemia is common in Indonesia, affecting an increasing number of individuals. There are no consistent estimates of thalassemia prevalence available, but the best estimates vary from 5% to between 6 and 10% (40).

Sanitation may be used as a proxy for the presence of these other causes of anemia. Since the percent of households with poor sanitation did not significantly differ across survey waves and since poor sanitation was not found to be significantly associated with hemoglobin concentration or anemia status, it is not likely that these other causes can explain the observed trends.

The results of this analysis are consistent with the previous study in North Jakarta, which found no association between anemia prevalence and intake of fortified wheat flour (19). This analysis is also consistent with the study in Sri Lanka that found no effect of fortified flour on hemoglobin concentrations, and the study in central Asia that found anemia did not decrease after fortification in two of the five countries analyzed (9, 10).

Conclusion

Average hemoglobin concentration increased and anemia prevalence decreased between the pre- and post-fortification periods. These changes do not appear to be attributable to the introduction of mandatory wheat flour fortification. It is recommended that Indonesia update its fortification standard to meet WHO recommendations by either increasing the amount of electrolytic iron used or switching to a more bioavailable form of iron such as ferrous sulfate or ferrous fumarate, in addition to increasing the amounts of folic acid and zinc.

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Tables

Table 1. Household food expenditure categories as listed in the Indonesian Family Life Survey (21-23), grouped into flour- and heme-containing foods.

Flour-containing Foods	**Heme-containing Foods**
Sago/flour	Beef, mutton, water buffalo meat and the like
Noodles, rice noodles, macaroni, shrimp, other chips, and the like	Chicken, duck and the like
	Fresh fish, oysters, shrimp, squid and the like
Cookies, breads, crackers	Jerky, shredded beef, canned meat, sardine and the like

Table 2. Summary of household and individual characteristics for non-pregnant women of reproductive age across Indonesian Family Life Survey waves (21-23).

Characteristic	IFLS2 (1997)	IFLS3 (2000)	IFLS4 (2007/8)	p-value (ILFS2 vs 3)[a]	p-value (IFLS3 vs 4)[a]
Household					
Total households, n	4,665[1]	4,998[1]	5,382[1]		
Household size (people), median (Q1, Q3)	5 (4, 6)[1]	5 (4, 6)[1]	4 (3, 5)[1]	<0.0001	<0.0001
Household total monthly expenditures (rp[b]), median (Q1, Q3)	381,329.2 (239,491.7, 648,283.3)[2]	735,079.2 (482,408.3, 1,195,891.7)[3]	1,655,991.8 (1,077,354.2, 2,662,224.9)[4]	<0.0001	<0.0001
Household weekly expenditures on all foods (rp), median (Q1, Q3)	4,4025.0 (29,000.0, 69,950.0)[5]	90,300.0 (59,000.0, 136,700.0)[6]	184,500.0 (124,500.0, 277,500.0)[7]	<0.0001	<0.0001
Household weekly expenditures on flour foods (rp), median (Q1, Q3)	2,700.0 (1,000.0, 6,000.0)[8]	6,675.0 (3,000.0, 13,000.0)[9]	15,000.0 (7,200.0, 26,700.0)[7]	<0.0001	<0.0001
Percent of household weekly food expenditures spent on flour foods, median (Q1, Q3)	6.2% (2.8, 10.8)[5]	7.5% (4.0, 11.9)[6]	8.0% (4.5, 12.5)[7]	<0.0001	<0.0001
Household weekly expenditures on heme foods (rp), median (Q1, Q3)	5,000.0 (1,500.0, 11,000.0)[2]	10,000.0 (3,000.0, 23,000.0)[10]	19,000.0 (6,000.0, 40,500.0)[7]	<0.0001	<0.0001
Percent of household weekly food expenditures spent on heme foods, median (Q1, Q3)	11.1% (4.6, 19.3)[5]	11.8% (4.8, 20.4)[6]	10.3% (3.9, 17.9)[7]	<0.0001	<0.0001
Food expenditure category, n (%)[11, 12, 7]				<0.0001	<0.0001
Heme and flour foods	4,425 (76.6%)	4,621 (79.6%)	4,688 (80.5%)		
Flour, but not heme foods	703 (12.2%)	776 (13.4%)	860 (14.8%)		
Heme, but not flour foods	442 (7.7%)	274 (4.7%)	176 (3.0%)		
Neither heme nor flour foods	209 (3.6%)	138 (2.4%)	101 (1.7%)		
Reside in urban area, n (%)	2,780 (47.7%)[13]	2,831 (48.6%)[1]	3,134 (53.8%)[1]	0.3490	<0.0001

Poor sanitation, n (%)	1,125 (19.4%)[14]	1,205 (20.7%)[13]	1,186 (20.4%)[13]	0.0723	0.6630
Province of residence, n (%)[1]				0.5887	<0.0001
Aceh	--[c]	1 (0.0%)	--		
Bali	307 (5.3%)	311 (5.3%)	311 (5.3%)		
Bangka-Belitung	--	--	33 (0.6%)		
Banten	--	--	151 (2.6%)		
Jakarta	460 (7.9%)	447 (7.7%)	422 (7.2%)		
East Java	844 (14.5%)	847 (14.5%)	851 (14.6%)		
West Java	971 (16.7%)	1,002 (17.2%)	891 (15.3%)		
Central Java	795 (13.6%)	780 (13.4%)	784 (13.5%)		
South Kalimantan	270 (4.6%)	270 (4.6%)	265 (4.6%)		
East Kalimantan	--	1 (0.0%)	3 (0.1%)		
Central Kalimantan	--	--	2 (0.0%)		
Lampung	205 (3.5%)	206 (3.5%)	207 (3.6%)		
West Nusa Tenggara	383 (6.6%)	381 (6.5%)	380 (6.5%)		
Riau	--	10 (0.2%)	17 (0.3%)		
Riau Islands	--	--	7 (0.1%)		
South Sulawesi	323 (5.5%)	323 (5.5%)	315 (5.4%)		
West Sulawesi	--	--	10 (0.2%)		
North Sumatra	328 (5.6%)	317 (5.4%)	310 (5.3%)		
South Sumatra	257 (4.4%)	253 (4.3%)	219 (3.8%)		
West Sumatra	337 (5.8%)	329 (5.7%)	316 (5.4%)		
Yogyakarta	348 (6.0%)	350 (6.0%)	334 (5.7%)		
Individual					
Total individuals, n	5,828	5,828	5,828		
Age (y), median (Q1, Q3)	32 (23, 39)[1]	35 (26, 42)[1]	42 (33, 49)[1]	<0.0001	<0.0001
Height (cm), median (Q1, Q3)	150.3 (146.7,	150.6 (147.1,	150.5 (146.9,	<0.0001	0.0326

	154.0)[15]	154.2)[16]	154.2)[17]		
Weight (kg), median (Q1, Q3)	48.6 (43.6, 54.9)[15]	50.1 (44.3, 56.9)[18]	53.4 (46.6, 60.9)[12]	<0.0001	<0.0001
Currently married, n (%)	4,083 (70.2%)[19]	4,323 (74.2%)[1]	4,680 (80.5%)[14]	<0.0001	<0.0001
Current smoker, n (%)	117 (2.0%)[20]	141(2.4%)[21]	136 (2.3%)[12]	0.1578	0.7456
Among current smokers, cigarettes smoked per day, median (Q1, Q3)	6 (3, 12)[22]	5 (3, 10)[23]	5 (3, 10)[24]	0.0117	0.3214
Took iron pills in last month, n (%)	335 (7.8%)[25]	164 (3.5%)[26]	259 (5.0%)[27]	<0.0001	0.0002
Among those who took iron pills, number of pills taken in last month, median (Q1, Q3)	10 (4, 21)[28]	10 (5, 20)[29]	8 (3, 16)[30]	0.0978	0.2661
Highest level of education attended, n (%)[31, 32, 33]				<0.0001	0.0025
No education	595(10.2%)	522 (9.1%)	541 (9.4%)		
Pre-school	--	1 (0.0%)	--		
Basic education	3,733 (64.1%)	3,620 (63.2%)	3,587 (62.1%)		
Secondary education	1,205 (20.7%)	1,145 (20.0%)	1,091 (18.9%)		
Higher education	281 (4.8%)	421 (7.4%)	516 (8.9%)		
Other	7 (0.1%)	20 (0.4%)	39 (0.7%)		
Total number of pregnancies, median (Q1, Q3)	1 (1, 3)[34]	1 (1, 3)[35]	2 (1, 3)[36]	<0.0001	<0.0001
Adjusted Hb concentration (g/dL), mean (Q1, Q3)[d]	12.5 (11.5, 13.4)[37]	12.4 (11.5, 13.3)[38]	12.8 (11.9, 13.5)[1]	<0.0001	<0.0001
Anemia, n (%)[e]	1,829 (33.9%)[37]	2,050 (36.1%)[38]	1,469 (25.2%)[1]	0.0194	<0.0001

[1]n=5,828 [2]n=5,796 [3]n=5,816 [4]n=5,716 [5]n=5,650 [6]n=5,790 [7]n=5,825 [8]n=5,788 [9]n=5,814 [10]n=5,818 [11]n=5,779 [12]n=5,809 [13]n=5,827 [14]n=5,815 [15]n=5,471 [16]n=5,715 [17]n=5,789 [18]n=5,704 [19]n=5,820 [20]n=5,725 [21]n=5,795 [22]n=87 [23]n=110 [24]n=108 [25]n=4,301 [26]n=4,707 [27]n=5,204 [28]n=329 [29]n=160 [30]n=250 [31]n=5,821 [32]n=5,729 [33]n=5,774 [34]n=1,466 [35]n=897 [36]n=2,390 [37]n=5,390 [38]n=5,686

[a]Unless otherwise noted, the Wilcoxon signed-rank test was used for continuous variables and the chi-squared test was used for categorical variables [b]Year-end exchange rates from Indonesia rupiah to 1 USD: 3,499 (1997), 8,900 (2000), 9,330 (2007) (41) [c]Not [d]Hemoglobin concentrations were adjusted for smoking status and elevation in accordance with WHO recommendations (25) [e]Anemia was defined as having an adjusted hemoglobin concentration <12.0 g/dL (25)

Table 3. Change in hemoglobin (Hb) concentration and anemia prevalence from pre- to post-mandatory wheat flour fortification in Indonesia among non-pregnant women of reproductive age (n=5,828)

Pre- to post-fortification change in adjusted Hb (g/dL), mean (SD)		**Anemia prevalence, n (%)**		
	p-value[1]	**Pre-fortification**	**Post-fortification**	**p-value[2]**
0.32 (1.62)	<0.0001	1,982 (34.0%)	1,469 (25.2%)	<0.0001

[1]paired t-test [2]chi-squared test

Table 4. Average percent of a household's total food expenditures in the past week spent on heme- and flour-containing foods, classified by four spending categories among non-pregnant women of reproductive age in Indonesia.

		Heme and flour[a]	**Flour, no heme[b]**	**Heme, no flour[c]**	**No heme, no flour**	**Overall**	**p-value[d]**
IFLS2[e] (1997)	Heme	15.2%[1]	--[f]	16.7%[3]	--	13.0%[4]	<0.05
	Flour	8.5%[1]	8.8%[2]	--	--	7.6%[4]	>0.05
IFLS3 (2000)	Heme	16.2%[5]	--	18.3%[7]	--	13.7%[8]	<0.05
	Flour	9.3%[5]	9.8%[6]	--	--	8.7%[8]	>0.05
IFLS4 (2007/8)	Heme	14.5%[9]	--	16.3%[11]	--	12.2%[12]	>0.05
	Flour	9.6%[9]	10.3%[10]	--	--	9.3%[12]	<0.05

[1]n=4,323 [2]n=686 [3]n=439 [4]n=5,650 [5]n=4,604 [6]n=775 [7]n=273 [8]n=5,790 [9]n=4,688 [10]n=860 [11]n=176 [12]n=5,825

[a]Within this category, p<0.05 comparing percent spent on heme-containing foods between IFLS2 and IFLS3, IFLS2 and IFLS4, and IFLS3 and IFLS4; p<0.05 comparing percent spent on flour-containing foods between IFLS2 and IFLS3, IFLS2 and IFLS4, and IFLS3 and IFLS4 [b]Within this category, p<0.05 comparing percent spent on flour-containing foods between IFLS2 and IFLS3 and between IFLS2 and IFSL4; p>0.05 between IFLS3 and IFLS4 [c]Within this category, p>0.05 comparing percent spent on heme-containing foods between IFLS2 and IFLS3, IFLS2 and IFLS4, and IFLS3 and IFLS4 [d]Comparison between individual spending categories within each survey wave [e]Indonesia Family Life Survey (IFLS) [f]Not applicable

Table 5. Average amount of household weekly food expenditures on all food items (rp) stratified by spending category.

	Heme and flour[a]	**Flour, no heme**[a]	**Heme, no flour**[b]	**No heme, no flour**[a]	**p-value**[c]
IFLS2 (1997)	65,112.2[1]	35,412.5[2]	43,615.9[3]	26,679.9[4]	<0.05[d]
IFLS3 (2000)	126,495.4[5]	68,381.7[6]	80,549.5[7]	58,236.1[8]	<0.05[e]
IFLS4 (2007)	267,179.4[9]	159,840.0[10]	229,718.1[11]	105,549.5[12]	>0.05[f]

[1]n=4,323 [2]n=686 [3]n=439 [4]n=202 [5]n=4,604 [6]n=775 [7]n=273 [8]n=138 [9]n=4,688 [10]n=860 [11]n=176 [12]n=101

[a]Within this category, p<0.05 comparing Hb between IFLS2 and IFLS3, IFLS2 and IFLS4, and IFLS3 and IFLS4 [b]Within this category, p<0.05 comparing Hb between IFLS2 and IFLS4 and between IFLS3 and IFLS4; p>0.05 between IFLS2 and IFLS3 [c]p-value for comparing Hb between all possible pairs of spending categories [d]Except for the comparison between the flour, no heme and the heme, no flour spending categories and between the flour, no heme and the no heme, no flour spending categories, for which p>0.05 [e]Except for the comparison between the flour, no heme and the heme, no flour spending categories, between the flour, no heme and the no heme, no flour spending categories, and between the heme, no flour and the no heme, no flour spending categories, for which p>0.05 [f]Except for the comparison between the heme and flour and the flour, no heme spending categories and between the heme and flour and the no heme, no flour spending categories, for which p<0.05

Table 6. Average adjusted hemoglobin (Hb) concentration (g/dL) and standard deviation, classified by spending category, among non-pregnant women of reproductive age in Indonesia.

	Heme and flour[a]	**Flour, no heme**[b]	**Heme, no flour**[b]	**No heme, no flour**[c]	**p-value**[d]
IFLS2 (1997)	12.4 (1.5)[1]	12.4 (1.6)[2]	12.4 (1.6)[3]	12.3 (2.0)[4]	>0.05
IFLS3 (2000)	12.3 (1.5)[5]	12.3 (1.5)[6]	12.2 (1.5)[7]	12.2 (1.6)[8]	>0.05
IFLS4 (2007)	12.7 (1.5)[9]	12.5 (1.5)[10]	12.6 (1.5)[11]	12.5 (1.4)[12]	>0.05[e]

[1]n=4,104 [2]n=670 [3]n=390 [4]n=191 [5]n=4,512 [6]n=762 [7]n=265 [8]n=132 [9]n=4,688 [10]n=860 [11]n=176 [12]n=101

[a]Within this category, p<0.05 comparing Hb between IFLS2 and IFLS3, IFLS2 and IFLS4, and IFLS3 and IFLS4 [b]Within this category, p<0.05 comparing Hb between IFLS3 and IFLS4; p>0.05 between IFLS2 and IFLS3 and between IFLS2 and IFLS4 [c]Within this category, p>0.05 comparing Hb between IFLS2 and IFLS3, IFLS2 and IFLS4, and IFLS3 and IFLS4 [d]p-value for comparing Hb between all possible pairs of spending categories [e]Except for the comparison between the heme and flour spending category and the flour, no heme spending category, for which p<0.05

Table 7. Average anemia prevalence (%), classified by spending category, among non-pregnant women of reproductive age in Indonesia.

	Heme and flour[a]	Flour, no heme[a]	Heme, no flour[b]	No heme, no flour[c]	p-value[d]
IFLS2 (1997)	33.6[1]	35.7[2]	32.3[3]	37.2[4]	<0.05
IFLS3 (2000)	36.2[5]	34.3[6]	39.3[7]	37.1[8]	<0.05
IFLS4 (2007)	24.8[9]	27.0[10]	25.0[11]	27.7[12]	<0.05

[1]n=4,104 [2]n=670 [3]n=390 [4]n=191 [5]n=4,512 [6]n=762 [7]n=265 [8]n=132 [9]n=4,688 [10]n=860 [11]n=176 [12]n=101
[a]Within this category, $p<0.05$ comparing anemia status between IFLS2 and IFLS4 and between IFLS3 and IFLS4 [b]Within this category, $p<0.05$ comparing anemia status between IFLS3 and IFLS4; $p>0.05$ between IFLS2 and IFLS4 [c]Within this category, $p>0.05$ comparing anemia status between IFLS2 and IFLS4 and between IFLS3 and IFLS4 [d]Comparison between categories using the no heme no flour category as the reference

Table 8. Average adjusted hemoglobin concentration (g/dL) stratified by place of residence among non-pregnant women of reproductive age in Indonesia.

	Urban	Rural	p-value[a]
IFLS2 (1997)[1]	12.3	12.4	0.0092
IFLS3 (2000)[2]	12.3	12.3	0.9987
IFLS4 (2007)[3]	12.6	12.7	0.4495

[1]n=5,389 [2]n=5,686 [3]n=5,828
[a]t-test

Table 9. Average anemia prevalence (%) stratified by place of residence among non-pregnant women of reproductive age in Indonesia.

	Urban	Rural	p-value[a]
IFLS2 (1997)[1]	35.0	32.9	0.1055
IFLS3 (2000)[2]	35.8	36.3	0.6958
IFLS4 (2007)[3]	25.1	25.4	0.8110

[1]n=5,389 [2]n=5,686 [3]n=5,828
[a]Chi-squared test

Table 10. Bivariate associations using linear regression between adjusted hemoglobin concentration and independent variables of interest among non-pregnant women of reproductive age in Indonesia.

Continuous/Binary Variables	**Estimate**[a]	**Standard error**	**t-value**	**p-value**
Age (y)	0.000818	0.001174	0.70	0.4858
Height (cm)	0.001127	0.002334	0.48	0.6293
Weight (kg)	0.01749	0.001274	13.73	<0.0001
Currently married	0.04087	0.02961	1.38	0.1675
Current smoker	-0.09994	0.08833	-1.13	0.2579
Number of cigarettes smoked per day	-0.01394	0.01391	-1.00	0.3161
Took iron pills in last month	-0.2182	0.05908	-3.69	0.0002
Number of iron pills taken in past month	-0.01131	0.002946	-3.84	0.0001
Total number of pregnancies	-0.01280	0.01130	-1.13	0.2577
Household size (people)	-0.04061	0.006202	-6.55	<0.0001
Reside in urban area	-0.01040	0.02747	-0.38	0.7050
Poor sanitation	-0.03492	0.02945	-1.19	0.2356
Monthly household expenditures (rp)	$2.601*10^{-8}$	0	Infinity	<0.0001
Household weekly food expenditures (rp)	$1.644*10^{-7}$	0	Infinity	<0.0001
Quintiles of household weekly food expenditures	0.06139	0.007762	7.91	<0.0001
Percent of household weekly food expenditures spent on heme foods	-0.00087	0.001089	-0.80	0.4228
Percent of household weekly foods expenditures spent on flour foods	0.006279	0.001739	3.61	0.0003
Household weekly food expenditures spent on heme foods (rp)	$4.396*10^{-7}$	0	Infinity	<0.0001
Household weekly food expenditures spent on flour foods (rp)	$1.117*10^{-6}$	0	Infinity	<0.0001
Multilevel Categorical Variables			**F-statistic**	**p-value**
Highest education level attended (ref[b]=no education)			5656.21	<0.0001
Household spending category (ref=no heme, no flour foods)			1.48	0.2174
Province (ref=West Java)			1361.19	<0.0001
Survey wave (ref=IFLS4)			130.41	<0.0001

[a]SAS's proc mixed procedure was used and, an unstructured correlation structure was applied with a robust estimator, taking into consideration the correlation among women and households and repeated measures [b]Reference level used for comparison of categorical variables

Table 11. Effect estimates for the final linear regression model for adjusted hemoglobin concentration among non-pregnant women of reproductive age in Indonesia.

Effect	Estimate[a]	Standard Error	t-value	p-value
Intercept	11.7571	0.09422	124.79	<.0001
Survey wave (ref[b]=ILFS4)				
IFLS2	-0.2284	0.03016	-7.57	<.0001
IFLS3	-0.3505	0.02699	-12.99	<.0001
Weight (kg)	0.01600	0.001396	11.46	<.0001
Number of iron pills taken in last month	-0.01073	0.002831	-3.79	0.0002
Household size (people)	-0.03084	0.007351	-4.20	<.0001
Percent of household weekly food expenditures spent on flour foods	0.006971	0.001987	3.51	0.0005
Province (ref=West Java)				
North Sumatra	0.2505	0.07576	3.31	0.0009
West Sumatra	0.4456	0.07555	5.90	<.0001
South Sumatra	-0.1616	0.08642	-1.87	0.0615
Lampung	0.01632	0.08869	0.18	0.8540
Jakarta	0.01323	0.06518	0.20	0.8392
Central Java	0.4079	0.05768	7.07	<.0001
Yogyakarta	-0.2462	0.08443	-2.92	0.0035
East Java	0.1092	0.05332	2.05	0.0406
Bali	0.1604	0.07166	2.24	0.0252
West Nusa Tenggara	0.3217	0.06818	4.72	<.0001
South Kalimantan	0.02037	0.08393	0.24	0.8083
South Sulawesi	0.2036	0.07703	2.64	0.0082
Aceh	-1.7622	0.04334	-40.66	<.0001
Riau	-0.01297	0.2270	-0.06	0.9544
Central Kalimantan	0.3963	0.1102	3.60	0.0003
East Kalimantan	0.09693	1.0959	0.09	0.9295
Bangka-Belitung	0.2658	0.1850	1.44	0.1508
Riau Islands	-0.2189	0.4029	-0.54	0.5870
Banten	-0.1320	0.1220	-1.08	0.2794
West Sulawesi	-1.0073	0.6304	-1.60	0.1101

[a]SAS's proc mixed procedure was used and, an unstructured covariance structure was applied with a robust estimator, taking into consideration the correlation among women and households and repeated measures [b]Reference level used for comparison of categorical variables

Table 12. Assessment of potential confounders to the association between survey wave and anemia status using logistic regression among non-pregnant women of reproductive age in Indonesia.

Variables[a]	**Percent change in OR for the effect of survey wave (IFSL2) on anemia**	**Percent change in OR for the effect of survey wave (IFSL3) on anemia**
Age[b] (y)	13.99	9.41
Height (cm)	0.08	0.05
Weight (kg)	7.12	4.90
Currently married	0.01	0.01
Current smoker	0.07	0.02
Number of cigarettes smoked per day	0.04	0.02
Took iron pills in last month	0.56	0.28
Number of iron pills taken in past month	0.53	0.09
Highest education level attended (ref[c]=no education)[d]	0.64	0.19
Total number of pregnancies	2.27	2.20
Household size (people)	1.62	1.11
Monthly household expenditures (rp)	1.98	1.47
Percent of household weekly food expenditures spent on heme foods	0.07	0.17
Percent of household weekly foods expenditures spent on flour foods	0.53	0.19
Nominal household weekly food expenditures spent on heme foods (rp)	0.49	0.30
Nominal household weekly food expenditure spent on flour foods (rp)	0.07	0.04
Household weekly food expenditures (rp)	1.33	0.93
Quintiles of household weekly food expenditures	1.00	0.52
Household spending category (ref=no heme, no flour foods)	0.14	0.02
Reside in urban area	0.14	0.11
Poor sanitation	0.04	0.01
Province (ref=West Java)	--[e]	--

[a]Variables were assessed one at a time to determine if their inclusion in the model changed the odds ratio for the effect of survey wave by more than 10% from that in the model containing only survey wave. Unless otherwise noted, SAS's proc glimmix procedure was used and, an unstructured covariance structure was applied with a robust estimator, taking into consideration the correlation among women and households and repeated measures [b]Toeplitz covariance structure used [c]Reference level used for comparison of categorical variables [d]Identity covariance structure used [e]Could not be assessed

Table 13. Effect estimates for the final logistic regression model for anemia status among non-pregnant women of reproductive age in Indonesia.

Effect[a]	**Estimate**	**Standard Error**	**t-value**	**p-value**	**OR**[b] **(95% CI)**
Intercept	-1.6271	0.08622	-18.87	<0.0001	
Survey wave (ref[c]=ILFS4)					
IFLS2	0.5548	0.04334	12.80	<0.0001	1.74 (1.67, 1.82)
IFLS3	0.6044	0.03927	15.39	<0.0001	1.83 (1.76, 1.90)
Age	0.01295	0.001944	6.66	<0.0001	

[a]SAS's proc glimmix procedure was used and a Toeplitz covariance structure was applied with a robust estimator, taking into consideration the correlation among women and repeated measures [b]Odds ratio for the effect of survey wave on anemia status [c]Reference level used for comparison of categorical variables

Appendix

Table 14. Average adjusted hemoglobin concentration (g/dL) stratified by province of residence among non-pregnant women of reproductive age in Indonesia.

Province of residence	IFLS2[1]	IFLS3[2]	IFLS4[3]
Aceh	--[a]	10.4	--
Bali	12.5	12.1	12.9
Bangka-Belitung	--	--	12.9
Banten	--	--	12.4
Jakarta	12.1	12.3	12.6
East Java	12.3	12.3	12.6
West Java	12.3	12.2	12.5
Central Java	12.6	12.5	12.9
South Kalimantan	12.1	12.4	12.5
East Kalimantan	--	11.0	12.6
Central Kalimantan	--	--	12.9
Lampung	11.8	11.9	12.9
West Nusa Tenggara	12.5	12.4	12.8
Riau	--	12.9	12.1
Riau Islands	--	--	13.1
South Sulawesi	12.6	12.2	12.7
West Sulawesi	--	--	11.8
North Sumatra	12.8	12.6	12.6
South Sumatra	12.4	11.6	12.7
West Sumatra	13.0	12.5	13.0
Yogyakarta	12.1	12.1	12.3

[1]n=5,390 [2]n=5,686 [3]n=5,828
[a]Not applicable

Table 14. Average anemia prevalence (%) stratified by province of residence among non-pregnant women of reproductive age in Indonesia.

Province of residence	IFLS2[1]	IFLS3[2]	IFLS4[3]
Aceh	--[a]	100.0	--
Bali	31.4	40.4	19.0
Bangka-Belitung	--	--	24.2
Banten	--	--	31.1
Jakarta	41.1	37.5	27.3
East Java	34.7	35.1	25.2
West Java	37.7	37.6	31.0
Central Java	29.3	30.0	20.3
South Kalimantan	43.3	33.3	31.7
East Kalimantan	--	100.0	33.3
Central Kalimantan	--	--	100.0
Lampung	50.0	48.3	21.7
West Nusa Tenggara	24.5	28.8	18.7
Riau	--	11.1	41.2
Riau Islands	--	--	28.6
South Sulawesi	25.7	39.0	18.1
West Sulawesi	--	--	11.8
North Sumatra	27.4	27.8	26.8
South Sumatra	37.1	53.1	29.2
West Sumatra	20.5	31.6	21.5
Yogyakarta	41.1	41.6	31.1

[1]n=5,390 [2]n=5,686 [3]n=5,828
[a]Not applicable